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16. ABSTRACT

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Personal computers and environmental engineering

Part I—Trends and perspectives

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The effective application of environmental engineering principles and concepts is critical for the productive management of our aquatic resources. Environmental engineers, who interact frequently with policy makers and with the public, must therefore communicate effectively to provide an understanding of technical analyses.

The current microelectronic revolution has both negative and positive impacts on this information transfer process. On the negative side, the explosive growth and application of computers adds to the deluge of technical information that already threatens to engulf us. This flood of information, along with the mystique surrounding computers, widens the already sizable gap between the technological haves and have-nots.

On the positive side, new computer technology offers capabilities for organizing and communicating information that can bridge the gap between the engineers and decision makers. The widespread availability of microcomputers makes this task easier.

This article discusses how personal computers can be applied to environmental engineering. After explaining some of the differences between mainframe and personal computers, we will review the development of personal computers and describe the areas of data management, interactive computation, graphics, and simulation, where personal computers play a prominent role in the transfer of information. Next, we will discuss new trends and developments such as artificial intelligence and their potential impact on environmental engineering, and we will suggest how personal computers might change the practice of environmental engineering in the future.

The past

In the early years of film- and motion picture-making, cameras were large and unwieldy. Moreover, most of the first movie directors were recruited from the theater. Consequently, many early films amounted to no more than animated photographs of stage productions. Cameras were fixed before the stage, and the performers acted as they would in a theatrical setting. As a result, the film audience viewed movies with the aloof and spatially fixed perspective of the theatergoer.

This tendency persisted even as film technology advanced and cameras became more compact and portable. Only when directors such as the late Orson Welles burst on the scene was the unique potential of film as a communication medium exploited. Movie audiences were visually transported out of their seats and into the action through the intimacy of the close-up and nonverbal expressiveness that makes cinema such a potent art form.

Today, a somewhat analogous situation exists in computing. A historical perspective is useful for understanding current circumstances. Prior to the early 1970s, computing was monolithic in that large mainframe systems were the only option generally available. These machines could be acquired only by large organizations such as corporations, universities, government agencies, and the military because they were expensive to own, operate, and maintain. As might be expected, the centralized way computer hardware was configured had a profound impact on the manner in which engineers interacted with the machines and on how technical results were communicated to decision makers.

Most early mainframe computers (prior to the early 1970s) operated as batch-processing systems. This mode allowed little or no direct interaction between the engineer and the machine. Often there were significant delays between the time a batch job was submitted and the time the output was received. These batch programs usually were written in a high-level language such as FORTRAN. As might be expected, the grammar and capabilities of these languages were consistent with the computer hardware in use at the time. Consequently, software written during this period exhibited the characteristics of the centralized computing environment.

In the early 1970s, the introduction of integrated circuits resulted in computers that were significantly faster, cheaper, and smaller. Time-sharing systems were developed so that several independent users could use a large mainframe computer simultaneously. Access was accomplished through telephone cables, and users were charged in a fashion similar to the way a utility company bills customers. Stimulated by these developments, programmers wrote software to allow users to submit programs and data directly to the computer and receive a prompt reply. Whereas the interaction between the user and the mainframe computer was equivalent to sending a message in a bottle, the time-sharing systems permitted a real-time dialogue between the user and the machine.

Although time sharing boomed for a while and certainly advanced the cause of the small user, the real breakthrough

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Advances in microcomputer technology have helped the environmental engineer much like new concepts in photography helped the movie director

came in the early 1970s, when minicomputers were introduced. Minicomputers are essentially scaled-down versions of large mainframe machines. Nevertheless, they are more than adequate for many scientific and environmental engineering applications (*1*). More importantly, they are affordable for most small engineering firms and for some individuals.

The great increase in user control and access ushered in by time sharing and minicomputers culminated in the development of the personal computer or microcomputer. These small but powerful machines are expressly designed for the individual and are financially feasible for most practicing engineers. The miracle of the microelectronic revolution is that for an affordable price, today's environmental engineer can have easy access to a computer that is superior in performance and capability to most of the early mainframe machines.

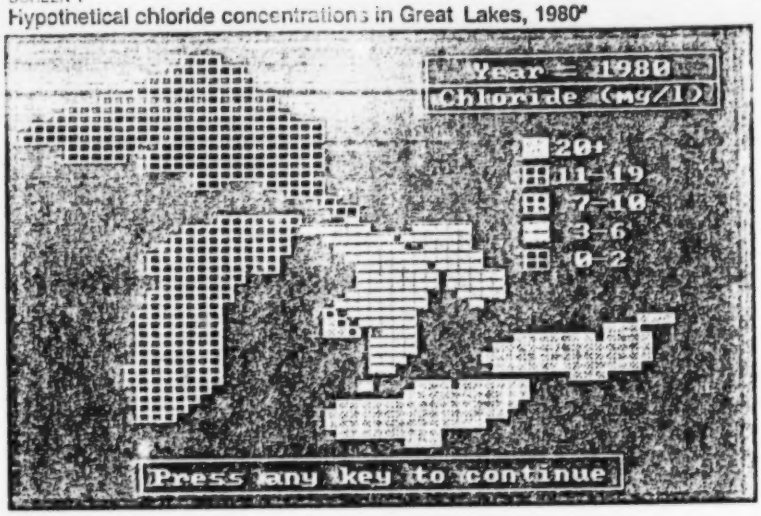
To exploit their capabilities effectively, however, this array of hardware must be accompanied by adequately designed software. Unfortunately, most existing software for environmental engineering systems was originally developed for mainframe computers. Moreover, many of these programs are being translated for implementation on personal computers with little or no modification. This practice is similar to that of early movie directors who applied theatrical principles to movies rather than exploiting the unique qualities of the new art form. Likewise, verbatim translation of mainframe-oriented software does not tap the immense potential of microcomputers to facilitate user interaction. In the following sections, we will demonstrate how attributes of personal computer hardware and software can be exploited to bridge the gap between the machine and the engineer, as well as between the engineer and the decision maker.

The present

Several unique aspects of personal computers—data management, interactive computation, graphics, and simulation—enhance effective communication between environmental engineers and decision makers.

Data management. Several commercially available data management software packages designed for personal use have been developed for microcomputers that are changing the way environmental engineers handle data. With mainframe computers, data are stored on cards or on tapes and often are difficult to use without elaborate preparations (for example, STORET). Microcomputer data management, however, allows the user to review, sort, modify, retrieve, and store data easily, which improves engineering analysis and decision making.

Hypothetical chloride concentrations in Great Lakes, 1980*



*Color shows different concentrations; graphics are generated by IBM-PC.

In addition, the display of data can be much more effective and interesting with the personal computer because of its interactive nature and its ability to represent data graphically. Screen 1 shows a microcomputer screen display of projected chloride data for the Great Lakes. Such data normally are stored in computer files or are presented in tabular formats that are often difficult to interpret. The color graphic presentation is a dramatic improvement over traditional methods.

The computer-generated figures presented in this paper were programmed for the IBM-PC. A complimentary copy of the software can be obtained by mailing a double-sided, double-density 5-1/4 inch diskette to Limno-Tech, Inc., 2395 Huron Parkway, Ann Arbor, Mich. 48104.

Interactive computations. Electronic spreadsheets, a special type of mathematical software for personal computers, allow engineers to enter and perform calculations in rows and columns of data. The spreadsheet is a computerized version of a large piece of paper or worksheet on which a complex calculation can be spread out, displayed, and modified.

Spreadsheets have a number of advantages that have contributed to their immense popularity. They are easy to use and understand, and they provide an organized record of computations. Because the entire calculation is automatically updated when any entry on the spreadsheet is changed, they are ideal for "what if ?" types of analyses. This latter aspect adds a powerful new dimension to environmental engineering problem-solving activities.

A sample computer screen of a spreadsheet is shown in Screen 2 (*2*). This spreadsheet computes the output concentration and efficiency of a completely mixed treatment system. The engineer moves the cursor vertically or horizontally to change the value of individual parameters in a quick and efficient fashion. As data for some of the parameters are changed, other values are computed internally and displayed immediately. This computational procedure encourages engineers and decision makers to consider alternatives that might not be explored with less convenient software. Finally, the spreadsheet provides a handy means of entering data and serves as a well organized summary of the equations and input parameters. It can be printed, reproduced, and published in a report.

Graphics. It often is remarked that "one picture is worth a thousand words." This saying holds true whether we are assimilating information or transferring it to others. Graphic illustrations are valuable vehicles for conveying information, ideas, and concepts to an audience. In addition, visualization is a prerequisite for understanding otherwise abstruse concepts and phenomena. Computer graphics have great potential in environmental engineering because of the continual need to communicate abstract information and findings to decision makers and the public.

The color graphic capabilities of microcomputers add an exciting new dimension to this endeavor. Before computers came into use, hand-drafting was time-consuming and costly. Even after computers were invented, costs and logistical problems associated with using mainframe computers discouraged the widespread application of graphics. Personal computers and related equipment such as the "mouse" represent an immense potential to increase our ability to produce and modify drawings. The coordinates of an object can be de-

fined, and the computer can display it in two- and three-dimensional forms.

Screen 3 shows a computer screen with a graphic and animated display of a completely mixed treatment system. Animation in the form of moving arrows indicates the direction of flow on the computer screen. The cursor can be moved from box to box to enter data on the left side of the screen. The resultant output concentration is displayed in the box on the right. This software design combines the features of a spreadsheet with those of graphics and animation. The overall result brings engineering calculations to life for the decision maker. This illustration should be compared with the simple spreadsheet shown in Screen 2.

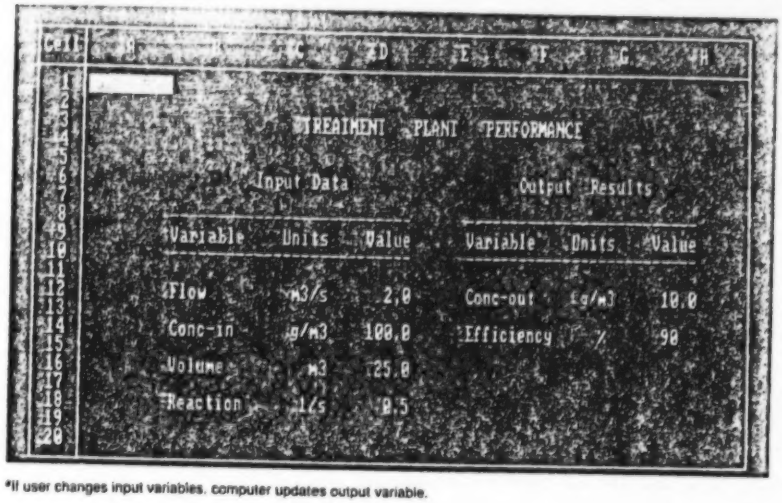
Simulation. Simulation is the process of conducting experiments with a model of a system. Although physical models can be employed, computer simulation involves the manipulation of a mathematical model. In this type of analytical simulation, the aim is to determine the response of the system when the input variables or parameters take on different values. The response usually is characterized by the value of one or more output variables.

The Monte Carlo method is a mathematical simulation technique that is useful for environmental analyses such as risk assessment. The model is run repeatedly using randomly generated values for the inputs and parameters. Rather than giving a single prediction, the Monte Carlo analysis provides a distribution for the output variable that yields valuable statistical information.

Screen 4 shows a computer screen of a Monte Carlo analysis for ammonia toxicity (*3*). The model is a function of random input values for pH, temperature, and flow. The software was designed specifically to communicate the essence of Monte Carlo analyses to decision makers. Computer color graphics and animation were employed to demonstrate visually how the predicted concentration distribution at the bottom of the screen is generated as a function of the random values selected at the top. Moving arrows on the screen are of great value in understanding and communicating the dynamics of objects, systems, and, in this case, technical concepts.

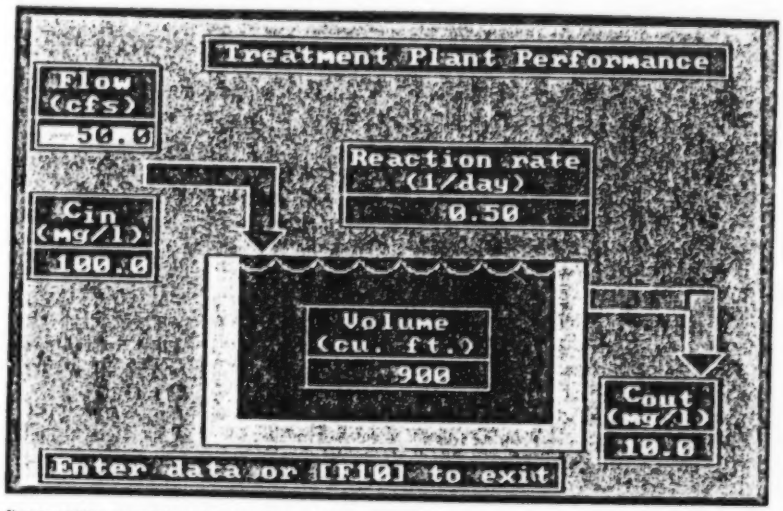
Cost is another aspect of personal computing that affects simulation. Historically, the major limitation of the Monte Carlo approach was its cost when it was implemented on a mainframe computer. Personal computers are much less limited in this regard. After the initial investment in a personal computer has been made, the major operating costs are for time. By comparison, power costs very little.

SCREEN 2
Spreadsheet showing treatment plant performance[a]



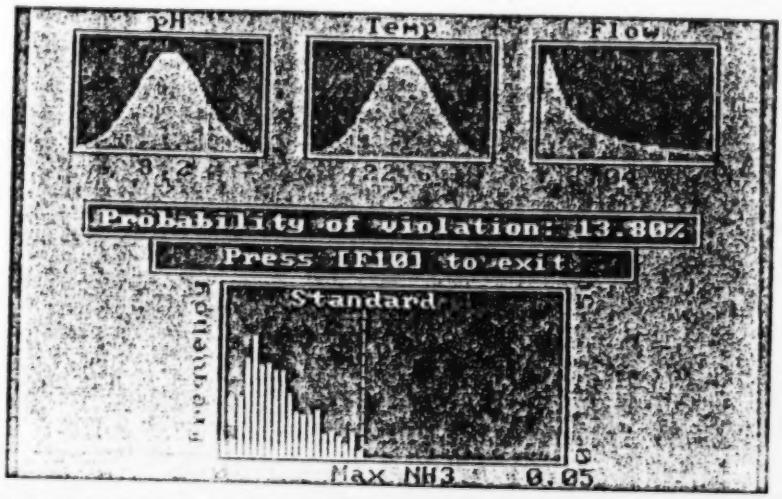
[a]If user changes input variables, computer updates output variable.

SCREEN 3
A completely mixed treatment plant[a]



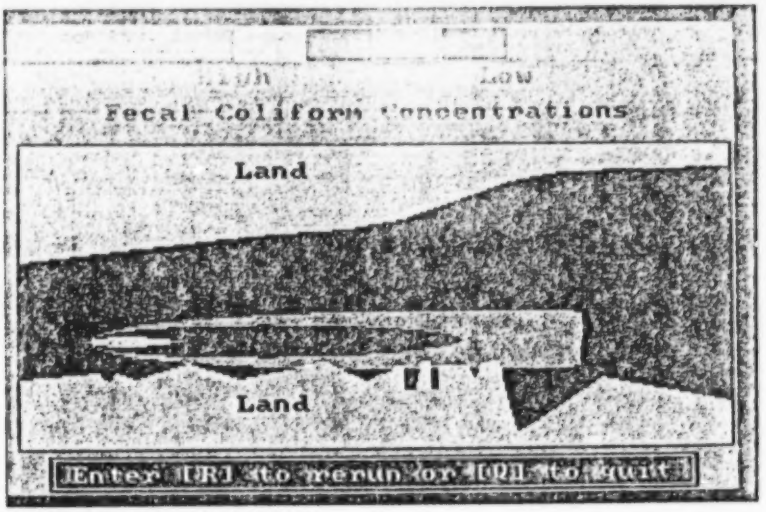
[a]Input variables are on left; performance data are shown on right.

SCREEN 4
Effects of pH, temperature, and flow on ammonia toxicity[a]



[a]Input values are random. Screen [illegible] during real-time simulation. Display demonstrates Monte Carlo analysis

Pollutant plume from discharge into a river*



*Color shows different pollutant concentrations.

Consequently, many large computations are run overnight on the personal computer.

One of the exciting aspects of simulation on personal computers is that they can easily be moved from location to location. Together with a large monitor or projection equipment, they can be employed as a powerful presentation device. A dramatic example occurred in a recent court case concerned with water supply from a reservoir in Virginia (*4*). An expert witness used a personal computer in the courtroom to present testimony regarding the pollution of the reservoir. Complex technical information was presented to the court by projecting computer graphics onto a large screen. A spreadsheet was used interactively to make predictions of the effect of anticipated land development on water quality in the reservoir. The judge and attorneys posed hypothetical scenarios, and the witness employed the computer model to generate immediate predictions of possible outcomes.

Another example of the application of portable personal computers involves the real-time simulation of oil and hazardous substance spills. Screen 5 shows a computer-generated screen associated with a model of a plume from a pollutant spill in a river (*5*). Such simulations can assist cleanup efforts. For instance, environmental engineers from a spill response team can enter up-to-the-minute water movement and wind data into a personal computer, which predicts where the spill is likely to come ashore. This information can be relayed to cleanup crews who must be on the spot to control damage.

The future

Artificial intelligence. Advances in personal computer hardware will increase computational efficiency and power and will be accompanied by fundamental changes in the way computers are applied. Most of these changes pertain to the emerging area of artificial intelligence—that is, the application of computers to simulate human thought processes. The potential impacts of artificial intelligence are contingent on the development of computers capable of parallel processing. In contrast with present-day computers that process information sequentially, a parallel processor executes several tasks simultaneously. Thus many of the bottlenecks associated with sequential machines can be mitigated, and computer efficiency can be enhanced.

Because such computers have yet to be developed, artificial intelligence is still in its formative stages. Two promising applications of artificial intelligence, however, are games and expert systems.

Most of us are familiar with video arcade games that use simulation and animation to permit players to interact with a computer to achieve an objective. Similar techniques have been employed to allow one or more users to interact with models of resource and environmental systems (*6*). Users have the opportunity to gain experience in making decisions related to population growth as a function of birth and death rates, standard of living, economic output, international trade, environmental quality, and energy use. The approach of these techniques incorporates three elements: a sophisticated simulation model of the system, a microcomputer that makes the computations portable, and a playing board and associated pieces that serve as an accounting device and aid in communication. Artificial intelligence could be used to mediate the input and output and provide an analysis and interpretation of results.

Expert systems are programs based on artificial intelligence techniques that contain a body of knowledge in a specific area. Their programs use this knowledge to draw conclusions in a manner that imitates human reasoning. As such, they can be thought of as computerized consultants. In general, expert system programs consist of a knowledge base that represents expertise in a particular field and an inference engine that manipulates the knowledge base to arrive at conclusions.

Expert systems can be employed in conjunction with environmental engineering in a variety of ways. For example, they can be developed to assist the model calibration processes. Sometimes modelers are not aware of the most recent approaches for determining model coefficients. This is particularly true regarding toxic substances. Expert systems can provide support and guidance in the form of a procedure for selecting the proper values of coefficients in such cases.

Model design. Advances in personal computer technology and availability will be increasingly important to environmental engineers. Personal computers are inexpensive and portable, and they have graphics and animation capabilities. On the other hand, their storage capacity is limited and they are relatively slow. Although many of these disadvantages will diminish as more efficient microprocessors are developed, in the short term we expect to see a trend toward the use of environmental systems models that have fewer computational demands. Engineers will be forced to design simpler and more elegant models to attain accurate results from a reasonable amount of computational effort. Use of these models will help limit the proliferation of needlessly complex models that may actually be less reliable than simpler models because of the errors associated with numerous uncertain model inputs.

Management applications. The convenience of microcomputers and simpler models will encourage engineers to consider more alternatives in the design and evaluation of environmental projects. The overall effect will move us in the direction of being more creative in our analysis and design activities. In addition, we will be able to present the results of our analyses to decision makers more effectively by capitalizing on the graphics and portability of microcomputers.

Overall, we expect to see technical and engineering analyses play a larger role in the decision-making process than they have in the past. This trend has already gained significant momentum; a greater number of consulting engineering firms, government officials, and those in academic fields use microcomputers in their day-to-day activi-

ties. Over the long run, we expect to see this trend accelerate as artificial intelligence and expert systems play more significant roles in engineering analyses. Thus environmental engineers may be more creative and effective in managing our aquatic resources wisely.

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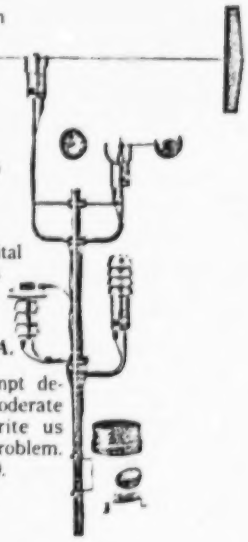

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